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Use-wear evidence confirms the earliest hafted chipped-stone adzes of Upper Palaeolithic in northern China

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Chipped-stone "adze-shaped objects" (ASOs) were identified from a few Upper Palaeolithic sites in northern China. Its morphological form resembles to ground-stone type-specific adze, but the function of the ASO has never been assessed. The objective of this study is to investigate the use function of this particular tool type recovered from the Hutouliang site in the Nihewan Basin of northern China. In this study, the lithic use-wear analysis is applied to examining microscopically edge-damages and surface-rounding of the tools in order to assess how they were employed. The result suggests that the ASO might have been used as woodworking tools with a hafted shaft, providing evidence for the appearance of the earliest hafted chipped-stone adzes prior to 10000 years ago in northern China. This study also demonstrates that the use-wear technique is an innovated and effective analytic appraoch to the study of stone tool functions that has been conventionally treated by typo-technological analyses. Stone tool use-patterns revealed by use-wear evidence would shed new insights on prehistoric adaptive strategies of modern human in northern China.

the end of Late Pleistocene, Hutuoliang site, adze-shaped object (ASO), use-wear analysis, composite tool

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Evolution of culture is considered as a process of adaptation driven by "an extrasomatic mechanism employed by a particular animal species in order to make its life secure and continuous"[1]. Human beings adapted themselves to environments both physically and culturally over the course of human evolution. Culturally, Palaeolithic adaptations can be interpreted in accordance with development of stone tools, in which technological innovations are illustrated by changes in manufacturing techniques and use-patterns of tool makers. Research on Palaeolithic stone tools, however, has always focused on typological study that compares changing forms and styles of stone tools over time. Tool function has been subjectively speculated based on morphological forms of working edges as well as ethnographic observations. No direct evidence has been offered for interpreting uses of stone tools in prehistory until recently. Without identifying actual functions of stone tools, many questions related to some specific archaeological materials remain un-answered; one of such examples is of "adze-shaped objects" (ASOs) that were unearthed from the Hutouliang site in Hebei Province.

As a new type of shaped tools, ASO emerged from a number of late Upper Palaeolithic sites in northern China, resembling in morphological form to woodworking "adze" which was made of either ground-stone, bronze, or iron in later periods. In general, ASO displays a trapezoid shape with a blunt top end or a triangular shape with a rough point tip. In most cases, it was unifacially chipped into a terraced dorsal surface while leaving a flat and smooth ventral surface. The relatively-thick bottom was likely worked into a stepped unifacially-retouched straight edge, and in some cases the top was also intentionally retouched. Giving such

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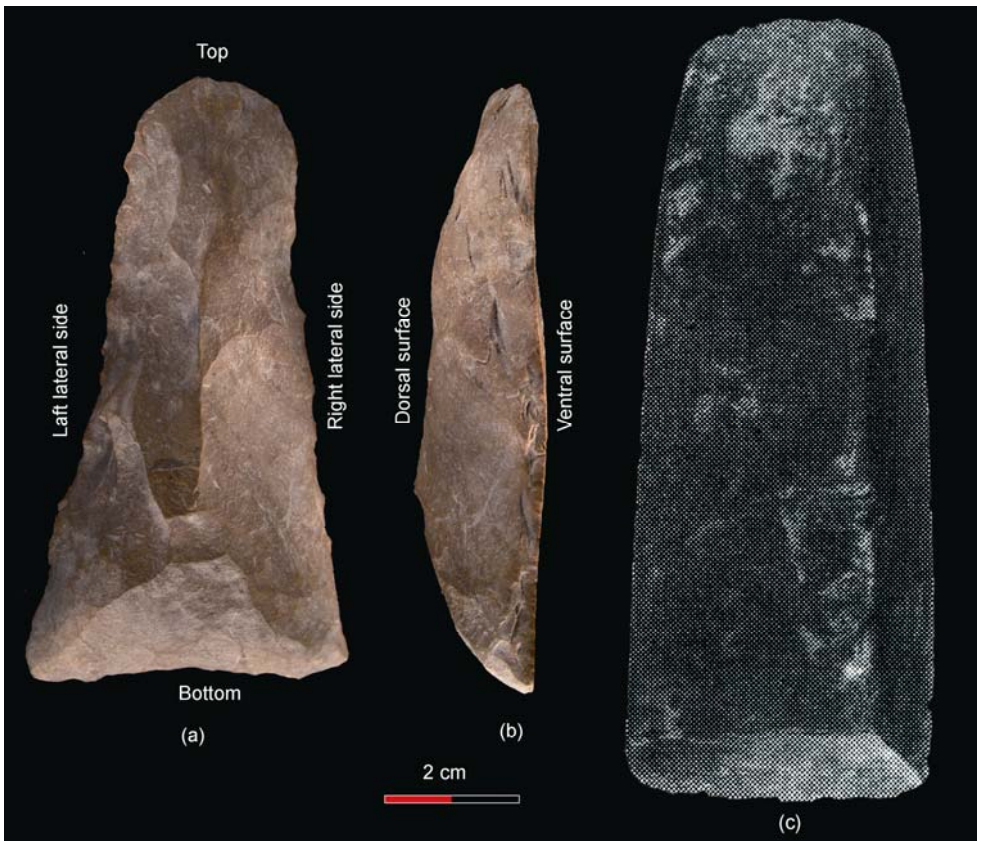

Figure 1 Diagram and terminology of ASO with comparison with a Neolithic ground-stone adze. (a) and (b) middle: the views of plan and profile of ASO (P5084) from Hutouliang site; (c) a ground-stone adze from a Neolithic site of Longshan period [4].

functionally-unspecified type-name as ASO, some scholars considered that these should be purposefully manufactured for some unknown use-tasks [2–4] (Figure 1). Made of ground-stone, bronze, and iron, adze itself is a common-known woodworking tool that is still in use today. Based on the similarity in appearance between ASO and the late adze, questions raise: what is the relationship between the chipped-stone ASO and late forms of adze? Would ASO be an early form of ground-stone adze, or was it a by-product of manufacturing? Was ASO used for woodworking? Was ASO hafted in use like recent adze? All of such questions concern a functional study of archaeological stone tools, which clearly could not be solved with a traditionally typological approach.

Lithic use-wear analysis is a newly developed analytic technique for the study of stone tool functions. The method was first initiated by a Russian scholar, Semenov, in the 1930s. Due to its methodological complexity, this analytic technique was not fully employed in North America and Europe until the 1980s—1990s [5–7]. Although the lithic use-wear analysis was first introduced into China as early as in the 1980s, its application to archaeological materials began to be systematically carried out only in the beginning of this century [8–10]. This analytic method is to examine microscopically used traces survived on working-edge of tools, leading to inferences and interpretations of tool use-patterns based on comparative observations with experimental references. The wear types were developed in various formations as a result of edge damages caused by different forces, worked materials, and directions of movements during the process of tool use. These use-wear patterns would provide direct evidence for how tools might have been employed and what materials might have been exploited. This innovated method in archaeological analysis has no doubt provided us with an opportunity to have a new perspective to understand human life in remote ancient societies [10].

The objective of this study is to explore tool use-patterning and human adaptive strategies during the transition from the Pleistocene to Holocene periods in northern China. The target materials are ASO artifacts recovered from the Hutouliang site. Among late Upper Palaeolihtic sites, Hutouliang yields the highest number of ASO artifacts [11]. The site, excavated in the late 1970s, was dated with radiocarbon ^{14}C to 11600–10000 years ago [11–16], when the globe was under extremely cold and dry climate during the Younger Dryas period. Hutouliang is a complex of 9 occupational localities within a range of 10 km area. Besides this distinct new tool type of ASO, other common chipped-stone tools include microlithics, scrapers, and points [12].

1 Analytical method and sampling

By employing different microscopic equipments and different observing focuses of use-wear, the analysis has two techniques: the low-power technique and the high-power technique. The low-power technique utilizes a stereoscopic microscopy up to 200 X magnification with a reflective lighting for examining primarily on edge-damage micro-fractures, whereas the high-power technique employs a metallurgical microscope with incident lighting for magnification between 500 X—2000 X (good for detecting surface wear polish). Because raw materials of Hutouliang artifacts appear to be in a variety of poor-quality and rough surface, polish was not well developed, thus not suitable for high-power microscopic examination. In this study therefore, we employed the low-power technique, using Nikon SMZ1500 stereoscopic microscope (with magnification between 7.5 X and 180 X), to focus on the records of micro-fractural scarring and edge rounding of use-wear. Polish and striation wear patterns were also observed, whenever possible.

The interpretations of use-patterns are derived from assessments based on overall combinations and configurations of use-wear that can be determined through reference collections including our own experimental use-wear data (over 200 experimental specimens) [17,18], as well as published works by other use-wear practitioners [19,20]. In those experiments, researchers chose appropriate raw mate rials and performed different use tasks, in accordance with research subjects related to archaeological interpretations. We recorded use-damages that were caused by various combinations of tool uses, so as to establish reliable relationships between tool motions (e.g., chop, plane, penetrate, drill, scrape, and cut) and worked materials (e.g., wood, meat, bone, and hide). The first two authors have carried out "blind tests" independently and their results are of 84% and 82% accuracy, respectively [18].

According to previous typological study, 25 artifacts from Hutouliang have been identified as ASO [11,21], all of which are subjected for the microscopic examination in this study. The main raw materials for making ASO is Siliceous Rocks (n=20), others includes Quartzite (n=4) and Agglomerate (n=1) [11]; overall raw materials of ASO have medium to poor grain inclusion and relatively high-developed internal fractures. From a plane-view there are three forms: rectangle, trapezoid, and triangle. They vary in sizes and weights (Table 1).

2 Results

The analytic results suggest that 14 ASOs retain positive use-wear (including both used wear and hafting wear). Half of these used ASOs (n=7) display both used working edges and hafting segments together. Three ASOs have only used wear while the remaining 4 ASOs show hafting wear only instead (Figure 2). In addition, one ASO displays an ambiguous use-wear pattern that could not be clearly assessed for either intentional used damage or by natural forces due to rough surface of the tool.

Most tools were found with more than one segment of working edge (or called Functional Unit). From 14 used ASOs, therefore, there are 32 Functional Units (FUs) found on different locations of the specimens. The used damages are commonly found on the tips or top segments as well as bottom edges, while hafting wear is seen on both left and right lateral edges.

2.1 Hafted composite tools

Eleven ASOs have clear hafting wear, accounting for at least 44% of the total of ASO artifacts identified at the site. This high frequency suggests that ASOs were made effectively for use as a composite tool with a hafted device/shaft. Therefore, 21 hafting wear FUs are the majority of use-wear found on ASOs (66% of all 32 FUs). Two features of hafting wear can be summarized as the following. First, micro-scars on the lateral edges, resulting from haftingrather than pressure retouch, appear in various forms in cluding snap or feathered terminations, but no percussion point resulted from retouch. Second, medium and heavy edge rounding that was caused by hafting is diagnostic as being presented between scars on lateral edges. Similar rounding is also shown on ridges of the dorsal surface where contacts with forced shaft or strings were made [19, 20] (Figure 3).

As far as locations of hafting FUs are concerned, most of hafting wear were found in both lateral edges of the tools;

Table 1 Measurements of Hutouliang ASOs [11]

	Max	Min	Mean	S.D.
Length (mm)	127.3	30.2	61.21	19.67
Width (mm)	73.3	25	44.69	11.45
Thickness (mm)	28.1	11	17.77	4.58
Weight (g)	210.7	10.8	63.58	45.38

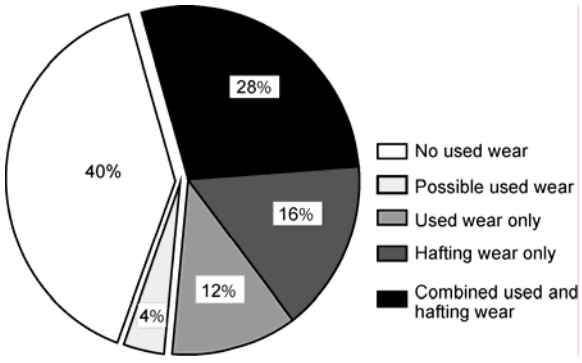

Figure 2 Distribution of ASO use-wear (total number = 25).

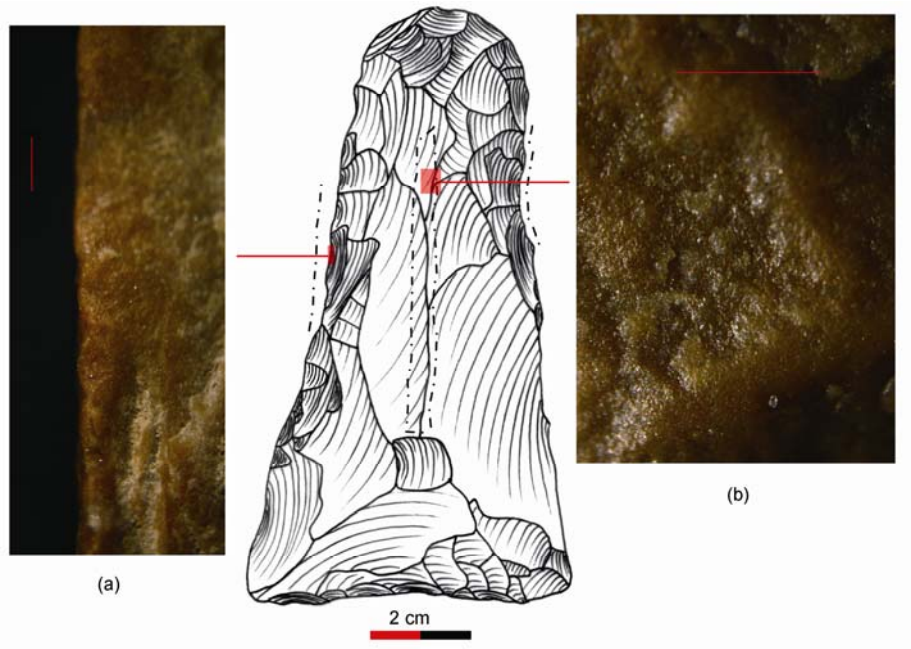

Figure 3 Hafting Wear (ASO: P5084). (a) Light rounding and micro-scars with multi-forms of terminations; (b) medium rounding on ridge of the dorsal surface (The dash-dotted line represents the location of hafting wear, and the red scales in micro-photos represent 1 mm in scale).

only a few are identified on segments of top, bottom, and dorsal ridges. According to the distribution of hafting wear locations, we have reasons to believe that strong contacts between ASO and the shaft were more likely to be concentrated on lateral sides or combination of one side edge and dorsal surface ridges. This pattern suggests that the hafting method be reconstructed as so-called "juxtaposed" hafting arrangement, in which the working tool was paralleled against wooden or bone haft attached with blinding [19,22] (Figure 4).

2.2 Earliest adze

Based on the use-wear evidence, this study can positively determine some of ASO tools to have been used as woodworking tools. These chipped-stone adzes, although made through different manufacturing techniques from those made on ground-stone and metal materials in later periods, shares similar morphological forms and especially similar use functions. Thus it is so far the earliest adze discovered in northern China.

At least 6 of such ASO tools were worked on their straight edge at the bottom where positive used wear is identified. Especially, four of these tools show microfractural scarring and rounding use-wear that are related to the hafting at their respective lateral edges at the top portion of the tools.

The use-wear observed at the bottom edges, as mentioned above, is dominated by light-to-medium rounding and medium-sized scars. They are distributed either bifacially or unifacially on dorsal side only. The terminations of the scars are featured with stepped and feathered characters, but occasionally with hinged. The combination of the used wear does not support for inferences of tool motions such as scraping and cutting/ sawing [23,24], instead the use-wear evidence is indicative of chopping and planning motions [18].

Among the pieces with both used wear and hafting wear, ASO P5048 exhibits the most relevant use-wear which allows us to assess it in confidence to be used as a typical adze. The use-wear rounding appears at the bottom; especially heavy-rounding is seen at both corners of the bottom in conjunction with the lateral sides, where small scars with feathered or stepped terminations were produced from use. On the ventral side of bottom edge there appear a few relative large size scars with feathered terminations, while in some segments scars were clustered with crushed pattern. Characteristics of medium-sized scars with feathered terminations and/or with stepped-terminations that were distributed unevenly along both dorsal and ventral sides and in combination with rounding, clearly point to a use-pattern that is related to woodworking such as planning activities. A hafted tool for planning woods can be undoubtedly regarded as a common function for adzing [24] (Figure 5).

2.3 Non-adzing tools

The use-wear results also suggest that some of ASOs were possibly used in two ways other than adzing. The one function is of penetrating and/or drilling on the tip, and the other is of scraping on lateral edges or bottom edge. In functional categories, some ASOs are non-adze tools even though they

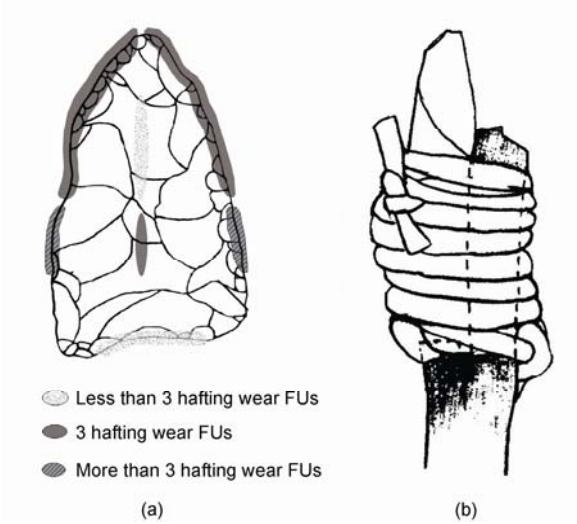

Figure 4 Hafting-wear distribution and diagram of hafting method. (a) The location and frequency of hafting wear; (b) "Juxtaposed" hafting arrangement.

have similar forms as ground stone adze.

(i) *Hafted projectile points.* Three ASOs can be functionally determined as hafted projectile points, 2 of which might have been used as processing meat. The common features of their use-wear are the concentration of used scars and rounding on the tip, while hafting wear appears clearly at the bottom or lateral edges near the bottom.

ASO P5042 is a good example of this kind. Large sized scars with stepped termination appear on the pointing tip, while on the lateral edges near the top distributed evenly a row of small sized scars associated with either shallow or deep feathered termination as well as light rounding, clearly indicative of the object being employed for meat processing. A single row of small and feathered scars along with well-developed rounding at the lower right-side lateral edge and also at left part of bottom edge, which is typical wear pattern resulting from wood contacts, suggests hafting function [24] (Figure 6).

(ii) *Multi-function tool.* One particular ASO, P5041, exhibits interesting used wear. One FU is located on right-side lateral edge near the tip, showing used rounding and unifacial but scattered distributed scars with shallow feather terminations. Based on the configuration of the use-wear, we assess this part of P5041 was used for scraping fresh wood. At the straight working edge at the bottom, for example, the use-wear combination (e.g., well-developed rounding along with middle sized scars that are distributed run-together and unifacially) suggests that the bottom of the P5041 was used to process dry wood [24]. From a morphological study, this ASO has both a pointed tip and a straight working edge at the bottom, thus it may be classified in typology as either a point, or an adze. Through use-wear analysis, we can assess that the piece was not made for one single defined function. Instead, it was likely prepared for multi-function purpose (Figure 7).

3 Summary and discussion

In this study we applied the lithic use-wear analysis to examining microscopically edge damages of 25 ASO typed artifacts from the Upper Palaeolithic Hutouliang site. This study reveals direct evidence of stone tool functions, indicating that ASO artifacts were manufactured for a special purpose to be used as composite tools (with a hafting device). Uses of ASO fall into two main functional categories: being used both for adze and for projectile points, in addition to one multi-functional tool. Therefore adzing must

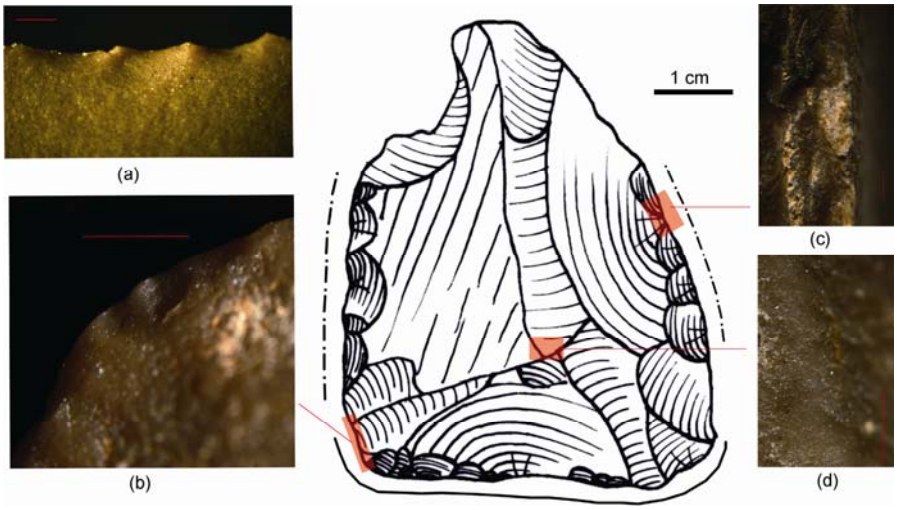

Figure 5 Used wear and hafting wear of adze (ASO: P5048). (a) Used wear of woodworking observed on an experimental specimen(USE 096), showing run-together micro-scars with feathered terminations; (b) used wear of ASO, rounding and run-together micro-scars with feathered and stepped terminations; (c) hafting wear, heavy rounding and stepped micro-scars in clumped distribution; (d) hafting wear, heavy rounding on ridge of dorsal surface (The solid line represents the location of used wear).

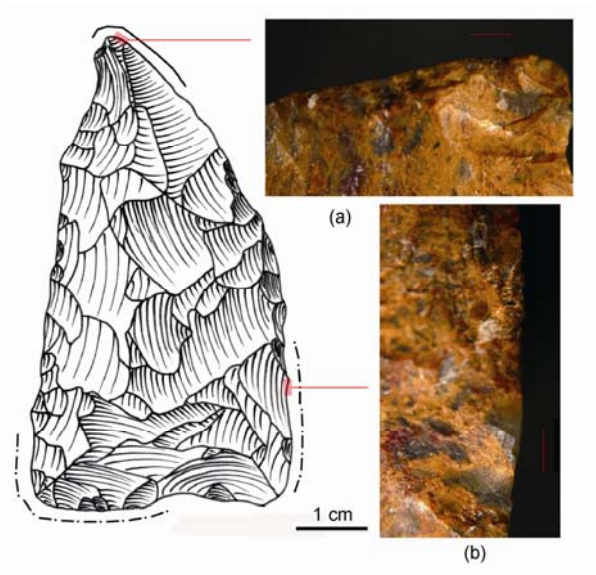

Figure 6 Used wear and hafting wear of a projectile point (ASO P5042). (a) Large sized scars with stepped terminations appearing on the tip, light rounding and a row of small sized scars with either shallow or deep feathered terminations near the tip; (b) a single row of small and feathered scars along with well-developed rounding.

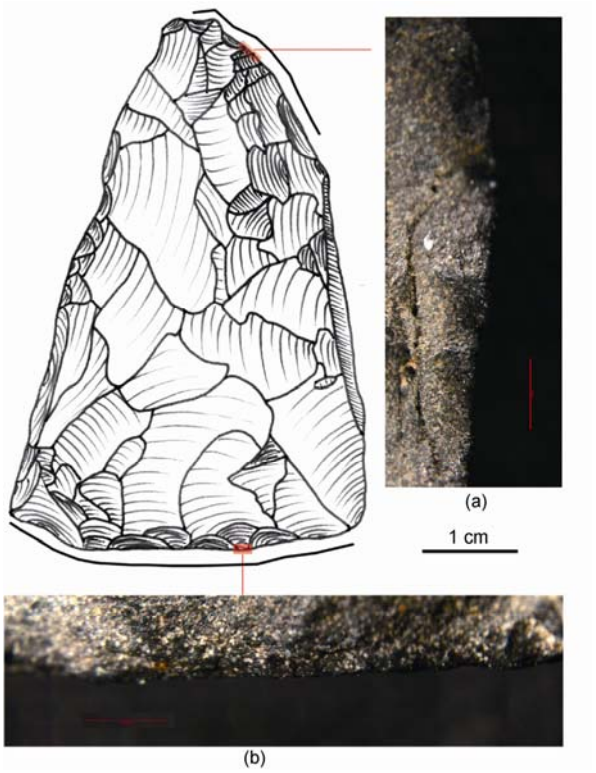

Figure 7 Used wear of a multi-function tool (ASO: P5041). (a) Scattered distributed scars with shallow feather terminations; (b) middle sized scars that are distributed run-together and unifacially.

have been a primary use function for ASO type tools from Hutouliang, inferring that the Hutouliang ASO could be the earliest chipped stone adze.

3.1 Use of complex hafting technique

The use of hafted tools in the Chinese Palaeolithic has long been speculated only based on morphological types of tools. For the first time, the use-wear evidence confirms the existence of hafted tools for Palaeolithic hunters and gatherers as early as 11000 years ago.

The study suggests that both adzes and project points in forms of ASO from the Hutouliang site were used as composite tools. Adze emerged as a new type of utilized tools at the end of Upper Palaeolithic, and continued to Neolithic periods. Projectile point was a common type during the Palaeolithic period, used as a hunting tool or weapon, for drilling, penetrating, or projecting. Given the ethnographic observations, projectile points were naturally considered to be used along with a hafting device, but no direct evidence has been offered until this study.

Interestingly, this study has assessed two different functions for 25 Hutouliang ASO artifacts. This contradicts the previous claim that they were typologically classified into a single group based on their morphological shapes. Our use-wear analysis discovers that some ASO were employed as hafted projectile tools and thus the tools had extensive unifacial-retouch at the bottom for the hafting purpose. However in previous study such retouched bottom of projectile point was mis-interpreted as a working edge of ASO. Therefore, it should be considered that 25 ASOs are in two different functional categories, indicated by the use-wear results.

A composite tool was created by hafting a shaft or a handling device attached to a shaped stone tool or a weapon for the best effectiveness of use function. Clearly, the manufacture of such composite tools needs careful preparation in design and requires a series of stages in tool-making process. The standardization of making composite tools such as adzes and projectile points reflects the development of human cognitions and adaptive behaviors. From a perspective of human evolution, appearance of composite tools has generally considered as an important behavioral character of modern human (*Homo sapiens sapiens*) [25,26].

However, shafts or handling devices in composite tools were usually made from organic materials like woods or bones, which were usually not preserved in archaeological context. In the Upper Palaeolithic of China, there is no single surviving hafting devices in any archaeological sites. So far, a well-preserved composite tool, a blade-sickle with a microblade glued to a carved bone handle, was reported from an Early Neolithic site near Beijing [27]. A groundstone adze was found with a surviving wood shaft at a Late Neolithic Liangzhu site (5000－4300 a BP) [28]. Due to no surviving evidence of organic hafting devices from Palaeolithic sites in China, use-wear becomes vital important evidence for determining the existence of Paleolithic composite tools.

In Africa, Europe, and West Asia, hafting use-wear

analyses also successfully determined the use of composite tools at some Middle Palaeolithic sites. For example, use-wear evidence from the 8-B-11 site in Sudan has pushed back the appearance of composite tools as early as 200000 years ago [20,25,29,30]. Thus, for this reason, it is important to assess hafting wear in lithic analysis of Chinese Palaeolitihic research, and our study demonstrates the success of this methodological application.

3.2 Function of chipped-stone adze and its significance

The discovery of use wear on ASO dismisses the notion that the ASO might be a working blank, or a preform, of ground-stone adze, and suggests that the Hutouliang ASOs were made as a final product for specific use functions. The use-wear evidence points to the fact that Hutouliang ASOs were extensively employed as wood chopping/planning tools, a similar function to that adze tools were used for [31]. The Dulong ethnic group, a modern hunter-gatherer society in high latitudes of Yunnan, utilized similar chipped-stone adze primarily for skinning the barks off the tree trucks as well as grooving wood logs. It is worthy to note that the hafting method of Dulong stone adze resembles the way in which Hutouling ASO hafting was reconstructed. Thus, its morphological forms, technological components (hafting), as well as its use function, all with no doubt suggest that Hutouliang ASO was the earliest known chipped-stone adze.

Before the emergence of metal products, adze was made on stone and used as a woodworking tool. In southern China, ground-stone adzes were frequently seen in Early Neolithic sites dated back to 8000 years ago. In European prehistory, chipped-stone adzes appeared in late Mesolithic (8000—5000 BC). Adzes were also found in prehistoric Southeast Asia, Egypt, New Zealand, and Northwest Coast of North America. All of these data suggest that stone adze appeared in Holocene period, but yet no evidence suggest their existence in Late Pleistocene age. The significance of this study is that, for the first time, the use-wear study confirms the use of Palaeolithic stone adze in northern China before 10000 years ago. It is also suggested that Hutouliang chipped-stone adze must have given a rise to widespread use of ground-stone adzes in Chinese Neolithic.

From ethnographic evidences from Australia, Africa, and Pacific Islands, we know that adzes are primarily used for manufacturing daily utensils and weapons made of wood [31–33]. Because of their concurrent appearance of ASO artifacts and microblade at Palaeolithic sites of North China, some scholars have speculated that ASO must have been used as composite tools for woodworking, but offered no evidence for this interpretation [3]. Our use-wear study has confirmed this hypothesis so far, but moreover we argue that the emergence of ASO being as adzing tools should have had "an extrasomatic mechanism". That is, during the Hutouliang period, the occupants had to cope with the extreme cold condition; human needs for building warm huts were likely in demands. Archaeologically, palaeolithic huts were identified in Eastern Siberia [34]. We thus propose that the development of ASO tools was not just for general use of woodworking, but was possibly a strategic adaptation for survivals. Our working hypothesis will be further tested when additional archaeological data become available.

In summary, the 25 Hutouliang ASOs under microscopically examination have been assessed to be in two separate functional categories: chipped-stone adzes for woodworking and projectile points for meat processing. Technologically, both functional-types of tools were finely retouched to include a hafting component. According to varied sizes and shapes, the use of Hutouliang ASO must have been through complicated stages from being manufactured, to utilized, to re-shaped, to main tained, and then to discarded, as their overall forms tended to be gradually smaller and lighter. Archaeologically, the fact that Hutouliang occupants have purposefully invented the functional-specific ASO is an excellent case study for strategic organization of lithic technology [35,36]. The differentiation of ASO functions may infer behavioral adaptation to adjust surviving strategies in coping with the cold weather conditions (building huts for example) in northern China. Specifically, two types of functional tools (adzes and projectile points) plus an additional multi-functional tool, all in forms of typologically defined ASO, had been utilized in the same time at the site, indicating a dynamic transformation in tool functions. Therefore, the emergence of the earliest chipped-stone adzes was the result of adapting tool functions to deal with changing living condition at the deteriorating environment during the Younger Dryas period.

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1 White A L. The Evolution of Culture. New York: McGraw-Hill Book Company, 1959. 8
2 Wang J, Wang X Q, Chen Z Y. Report on archaeological surveys at Xiachuan site, Shanxi Province (in Chinese). Acta Archaeol Sin, 1978, 3: 259–288
3 Xie F, Li J, Shi J M. Research on adze-shaped tools unearthed in Upper Paleolithic sites in China. In: The Paleolithic Culture in Northeast Asia (in Chinese). Seoul: Baishan Culture Press, 1996. 179–195
4 Lan Y F. The discovery of Longshan Culture lithic assemblages at Geshan in Sishui County, Shandong Province (in Chinese). Archaeology, 2008, 5: 92–94
5 Semenov S A. Prehistoric Technology. London: Cory, Adams and

Mackay, 1964
6 Keeley L H. Experimental Determination of Stone Tool Uses. Chicago: The University of Chicago Press, 1980
7 Odell G H. Stone Tools and Mobility in the Illinois Valley: from hunter-gatherer camps to agricultural villages. Michigan: International Monographs in Prehistory, Ann Arbor, 1996
8 Shen C, Chen C. Use-wear analysis (Low Power Method): research and practice, and a use-wear examination of the Xiaochangliang Lithic artefacts (in Chinese). Archaeology, 2001, 7: 62–73
9 Zhang S S. Book Review on 'Experimental Determination of Stone Tool Uses' (in Chinese). Acta Anthropol Sin, 1986, 5: 392–395
10 Gao X, Shen C. Application and future advancement of lithic use-wear studies in China. In: Gao X, Shen C, eds. Archaeological Study of Lithic Use-wear Experiments (in Chinese). Beijing: Science Press, 2008. 1–22
11 Zhu Z Y. The Study on Lithic Assemblage from the Hutouliang Site in North China (in Chinese). Dissertation for the Doctoral Degree. Beijing: Institute of Vertebrate Paleontology and Paleoanthropology, the Chinese Academy of Sciences, 2006. 98–109
12 Gai P, Wei Q. The discovery of Upper Palaeolithic Hutouliang site (in Chinese). Vert PalAsiat, 1977, 15: 287–300
13 Li X G, Liu G L, Xu G Y, et al. ^{14}C Dating report (PV) I (in Chinese). In: The Radiocarbon Dating Society of Chinese Quaternary Research Association, ed. Contribution to the Quaternary Glaciology and Geology (Special Issue on ^{14}C Dating). Beijing: Geological Publishing House, 1987. 17
14 Gai P. Microblade tradition around the northern pacific rim: a Chinese perspective. In: Institute of Vertebrate Paleontology and Paleoanthropology, ed. Contribution to the XIII INUQA. Beijing: Beijing Scientific and Technological Publishing House, 1991. 21–31
15 Xia Z K, Chen F Y, Chen G, et al. Environmental background of Paleolithic-Neolithic Transition in Nihewan Basin, North China (in Chinese). Sci China Ser D-Earth Sci, 2001, 31: 393–400
16 Xie F, Li J, Liu L Q. The Paleolithic Culture in Nihewan Basin (in Chinese). Shijiazhuang: Huashanwenyi Press, 2006. 162–176
17 Gao X, Shen C. Archaeological Study of Lithic Use-wear Experiments (in Chinese). Beijing: Science Press, 2008
18 Shen C. The Lithic Production System of the Princess Point Complex during theTransition to Agriculture in Southwestern Ontario, Canada. BAR International Series 991, 2001. 45–53
19 Rots V. Prehensile Wear on Flint Tools. Lith Technol, 2004, 29: 7–32
20 Rots V, Philip V P. Early evidence of complexity in lithic economy: core-axe production, hafting and use at Late Middle Pleistocene site 8-B-11, Sai Island (Sudan). J Archaeol Sci, 2006, 33: 360–371
21 Zhu Z Y. The adze-shaped tools Unearthed from Hutouliang Site (in Chinese). Northern Cultur Rel, 2008, 2: 3–8
22 Zhao J F, Song Y H, Chen H, et al. An experimental study of hafting Use-wear (in Chinese). In: Gao X, Shen C, eds. Archaeological Study of Lithic Use-wear Experiments. Beijing: Science Press, 2008. 145–176
23 Zhang X L, Wang C X, Zhang Y, et al. An experimental Study of Scraping Use-wear (in Chinese). In: Gao X, Shen C, eds. Archaeological Study of Lithic Use-wear Experiments. Beijing: Science Press, 2008. 83–106
24 Chen F Y, Cao M M, Guan Y, et al. An experimental study of woodworking Use-wear (in Chinese). In: Gao X, Shen C, eds. Archaeological Study of Lithic Use-wear Experiments. Beijing: Science Press, 2008. 41–60
25 Lombard M. Evidence of hunting and hafting during the Middle Stone Age at Sibidu Cave, KwaZulu-Natal, South Africa: a multianalytical approach. J Human Evol, 2005, 48: 279–300
26 Klein R G. Archaeology and the evolution of human behaviour. Evol Anthropol, 2000, 9: 17–36
27 Archaeology and Museum Study College of Peking University, Archaeological Center of Peking University, and Beijing Institute of Archaeology. Prehistoric Donghulin Site in Mentougou District, Beijing City (in Chinese). Archaeology, 2006, 7: 3–8
28 Xiao M L. The hafting methods and utilizations of stone adzes: the discovery of stone axes and adzes with a wooden haft for Liyang Shahe (in Chinese). Agr Archaeol, 1982, 2: 108–113
29 Gibson N E, Wadley L, Williamson B S. Microscopic residues as evidence of hafting on backed tools from the 60000 to 68000 year-old Howiesons Poort layers of Rose Cottage Cave, South Africa. S Afr Humanities, 2004, 16: 1–11
30 Büller J. Handling, hafting and ochre stains. In: Beyries S, ed. Industries Lithiques Tracéologie et Technologie Vol. 1: Aspects archéologiques. Oxford: BAR International Series 411. 1988. 5–32
31 Mitchell S R. The woodworking tools of the Australian Aborigines. J Royal Anthropol Inst Great Britain Ireland, 1959, 89: 191－199
32 Clark J D. Some Stone Age woodworking tools in Southern Africa. S Afr Archaeol Bull, 1958, 13: 144–152
33 Clark G. Traffic in stone axe and adze blades. Econ Hist Rev, 1965, 18: 1–28
34 Feng E X. Archaeology of Eastern Siberia and Far East (in Chinese). Changchun: Jilin University Press, 2002. 1–92
35 Binford L R. Organization and formation processes: Looking at curated technologies. J Anthropol R, 1979, 35: 255–273
36 Nelson M. The study of technological organization. In: Schiffer M, ed. Archaeological Method and Theory. Tucson: The University of Arizona Press, 1992. 57–100